

SYDNEY AMATEUR DIGITAL COMMUNICATIONS GROUP

INSTRUCTION MANUAL

(Preliminary)

Am7910 WORLD CHIP^R

FSK MODEM

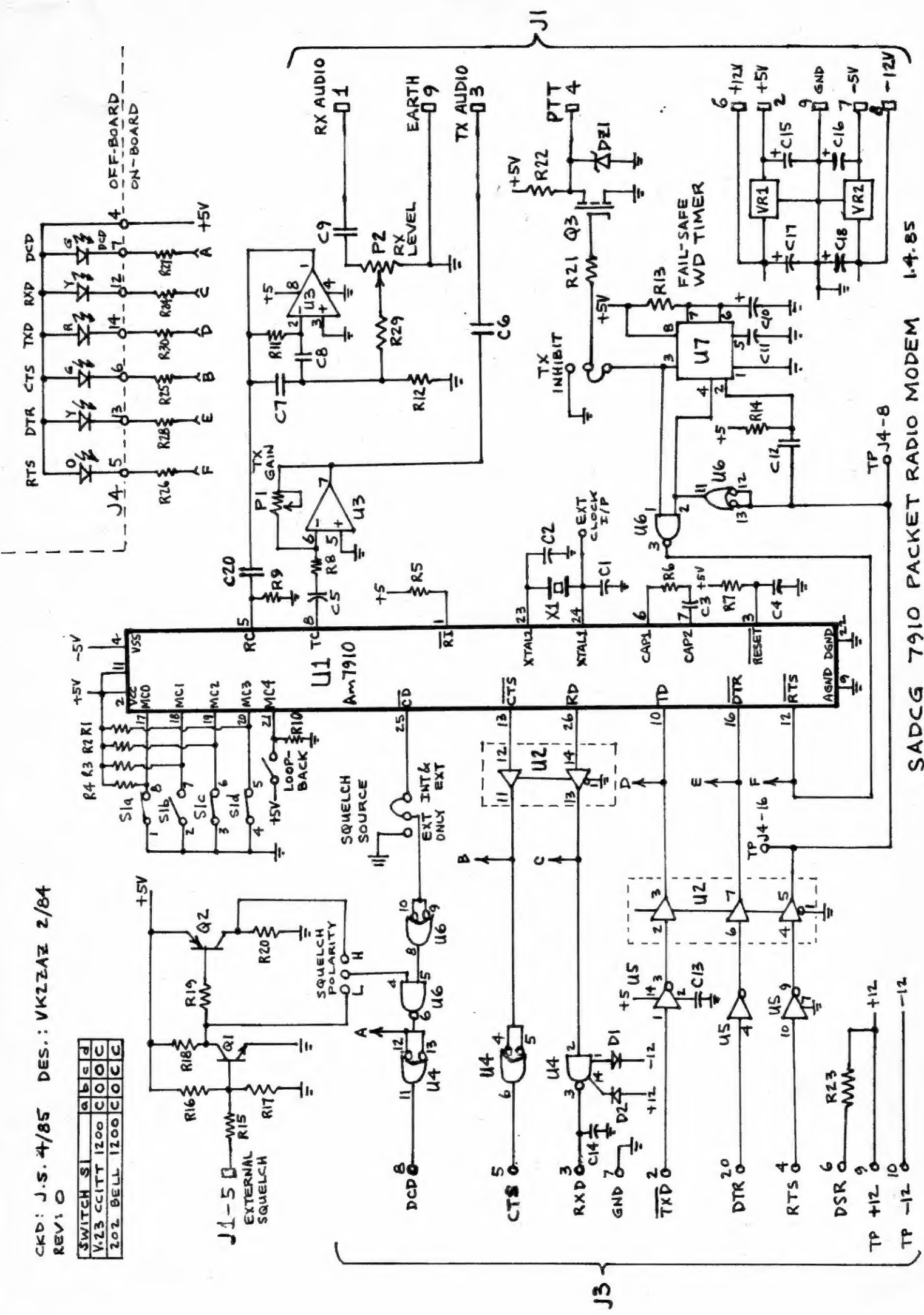
for the

VADCG Terminal Node Controller

April 12, 1985.

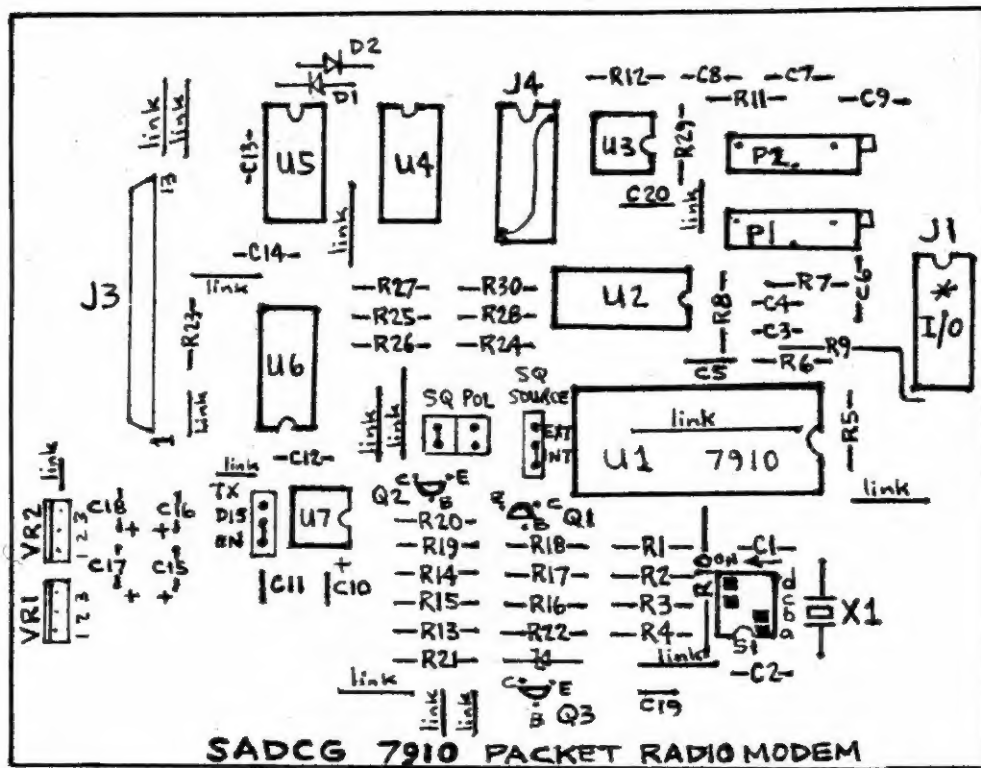
CKD: J.S. 4/85 DES.: VKZZAZ 2/84
REV: 0

SWITCH S1	a	b	c	d
V.23 CCITT 1200	C	Q	Q	C
202 BELL 1200	C	Q	C	C



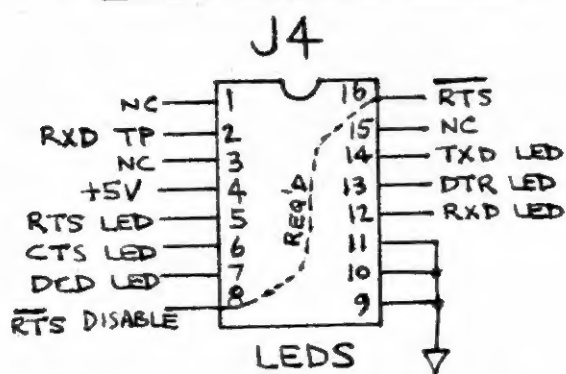
SADCG 7910 PACKET RADIO MODEM

COMPONENT OVERLAY

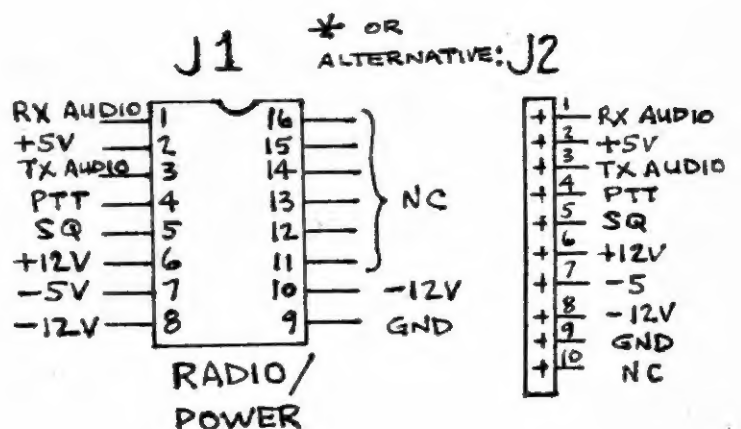
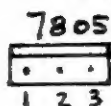


NOTES:

1. CONNECTOR DEFINITIONS



VIEW FROM TOP



REV.	0
DATE	1.4.85
DESIGN	VK2ZTN VK2ZAZ
CHK'D	VK2BVD

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PARTS LIST			
Component Designation	Qty	Value	Description
RESISTORS			
R1,2,3,4,5,15,19,21,23	9	4700	Ohms 5% 0.25 watt
R6	1	100	" "
R7	1	1M	" "
R8	1	47k	" "
R9,R13	2	100k	" "
R10,R14	2	10k	" "
R11	1 *	68k	" "
R12	1 *	1200	" "
R16	1	10k	" " (optional)
R17	1	10k	" " (optional)
R18, R20	2	2200	" "
R22	1	470	" " (optional)
R24,25,26,27,28,30	6	330	" "
R29	1 *	22k	" "
Potentiometers			
P1	1	50k	Trimpot or 1-turn pot
P2	1	2k	Trimpot or 1-turn pot
CAPACITORS			
C1, C2	2	22 pF	ceramic 50V
C3	1	0.002 mF (2000pf)	ceramic 50V or <i>silver mica (prc)</i>
C4	1	0.047 mF	223M monolithic ceramic metallized polyester S3 MKT 1818 or mono ceramic
C5, C6, C9	3	0.22 mF	monolithic ceramic 224 MSE
C7, C8, C11	3	0.01 mF	" " 103M
C10	1	100 mF	electrolytic 25V
C12,C19	2	0.1 mF	cer50V or mono cer 104M
C13, C14	2	470 pF	ceramic 50V
C15, C16	2	1 mF	tantalum 16V TAG
C17, C18	2	10 mF	tantalum 25V TAG
C20	1	0.33 mF	metallized polyester 10% WIMA 63-B-ST 2
Note: * Do not substitute - frequency determining elements (R12 will change centre frequency, adjust for equal MARK/SPACE tone levels)			

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INTEGRATED CIRCUITS				
U1	28 pin	1	Am7910	WORLD-MODEM ^R IC
U2	16 "	1	74LS367	Advanced Micro Devices Tristate Hex Bus Driver
U3	8 "	1	1458	Dual Op-Amp
U4	14 "	1	1488	Quad Driver (or 75188)
U5	" "	1	1489	Quad Receiver (or 75189)
U6	" "	1	74LS00	Quad 2-Input NAND
U7	8 "	1	7555	Timer IC (or NE555)
MISCELLANEOUS				
Q1		1	BC547	Si NPN switching transistor (BC-108, BC-548, DS-548, or 2N2222)
Q2		1	BC557	Si PNP switching transistor (BC-158, BC-178, BC-308, BC-213, BC-558, or 2N2906)
Q3		1	BC547	VFET or NPN transistor (BC-108, BC-548, DS-548)
D1, D2		2	1N914	Diodes (or 1N4148)
DZ1		1	"	zener diode (or 1N914)
VR1		1	7805	Regulator (optional) +5 Volt TO-220 case
VR2		1	7905	Regulator (optional) -5 Volt TO-220 case
Leds		6		2 Gr, 2 Yel, 1 Red, 1 Or
X1		1	HC18/U	2.4576 MHz +/- 0.01%
S1		1		DIP 4 position switch (or fixed strap)
J1		1		16 pin DIP I/O socket
J2		1	Utilux	KK Series - 10 position (not required if J1 used)
J3		1	DB-25S	Right Angle RS232 Connector (female - 0.1" pcb spacing)
<u>Jumpers</u>				
2 pin		2		(0.1" spaced) pin connector
3 pin		2		(0.1" spaced) pin connector
Links on pcb				(Wire-wrap wire or equiv. No.30 SWG Kynar ^R)

Pre-production Prototypes [S/N 001 to 010]

Defects List:

ERRATA SHEET

1. 7905 and 7805 regulators too close to DB-25S connector
- bend to suit
 2. Track break at D2 anode → soldered with jumper
 3. R9, C20 missing from board - required for DC isolation of U1-5
 - * C20 installed next to U3: track drilled and cut from U1-5
 - * R9 installed between C3 and R6 with one end to ground point below pin 8 of I/O DIP and other end soldered to track from U1 pin 5 as shown.
 4. Pin 4 of U3 reference supply changed from -5V to GND to keep signal to U1-5 within MOS-levels:
 - * Cut -5V track next to pin 4 of U3
 - * Join pins 3 and 4 of U3
 5. Loopback facility missing from board - added R10
 - * Cut earth track from pin 21 U1 (isolate pin 21)
 - * Re-establish earth track from pin 22 U1 to earth track under U2 (was isolated in previous step)
 - * Add a hole next to pin 21 of U1 and join one end of R10 to pin 21; connect the other end of R10 to the earth link hole below the 4 position DIP switch.
 6. Transistor Q1 orientation is reversed - artwork correction req'd.
 7. C4 capacitor lead spacing should be slightly larger.
 8. Lead of C6 too close to P1 if trimpot is used.
 9. Mounting holes near DB-25S edge to be moved back from board edge by 10 mm.
- * N.B. Ensure that link under U1 is installed before socket is soldered. Also install link next to VR2 before J3 is soldered.

Appendix A

Am7910

FSK MODEM

WORLD-CHIP™



Am7910

Advanced Micro Devices

April 1984

DISTINCTIVE CHARACTERISTICS

- Complete FSK MODEM in a 28-pin package – just add line interface
- Compatible with Bell 103/113/108, Bell 202, CCITT V.21, CCITT V.23 specifications
- No external filtering required
- All digital signal processing, digital filters and ADC/DAC included on-chip
- Includes essential RS-232/CCITT V.24 handshake signals
- Auto-answer capability
- Local copy/test modes
- 1200 bps full duplex on 4-wire line
- Pin-programmable mode section

Figure 1. Connection Diagram



012380-1

GENERAL DESCRIPTION

The Am7910 is a single-chip asynchronous Frequency Shift Keying (FSK) voiceband modem. It is pin selectable for baud rates of 300, 600 or 1200 bits per second and is compatible with the applicable Bell and CCITT recommended standards for 103/113/108, 202, V.21 and V.23 type modems. Five mode control lines select a desired modem configuration.

Digital signal processing techniques are employed in the Am7910 to perform all major functions such as modulation, demodulation and filtering. The Am7910 contains on-chip analog-to-digital and digital-to-analog converter circuits to minimize the external components in a system. This device

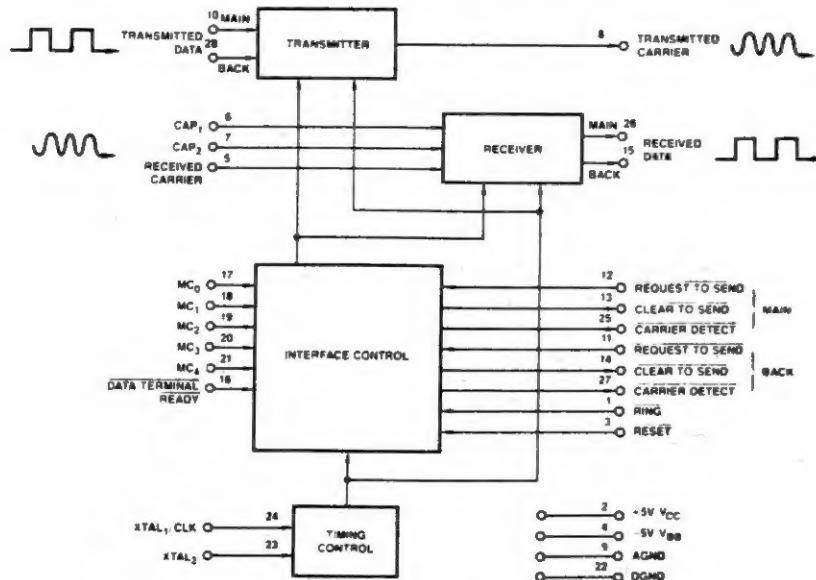
includes the essential RS-232/CCITT V.24 terminal control signals with TTL levels.

Clocking can be generated by attaching a crystal to drive the internal crystal oscillator or by applying an external clock signal.

A data access arrangement (DAA) or acoustic coupler must provide the phone line interface externally.

The Am7910 is fabricated using N-channel MOS technology in a 28-pin package. All the digital input and output signals (except the external clock signal) are TTL compatible. Power supply requirements are ≤ 5 volts.

Figure 2. Am7910 Block Diagram



012380-2

INTERFACE SIGNAL DESCRIPTION

MC₀-MC₄ (CONTROL INPUTS)

These five inputs select one of thirty-two modem configurations according to the Bell or CCITT specifications listed in Table 1. Only 19 of these 32 modes are actually available to the user.

Modes 0-8 are the normal operation modes. The 1200 Baud modes can be selected with or without a compromise equalizer.

Modes 16-25 permit loop back of the Am7910 transmitter and receiver. No internal connection is made. The user must externally connect the TRANSMITTED CARRIER pin (Figure 3) to the RECEIVED CARRIER pin if analog loopback is required. For digital loopback, external connection of RECEIVED DATA and TRANSMITTED DATA is required. Whenever a mode in this group is selected, the effect is to set all transmit and receive filters to the same channel frequency band so that loopback can be performed.

Modes 9-15 and 26-31 are reserved and should not be used.

DATA TERMINAL READY (DTR)

A LOW level on this input indicates the data terminal desires to send and/or receive data via the modem. This signal is gated with all other TTL inputs and outputs so that a low level enables all these signals as well as the internal control logic to function. A HIGH level disables all TTL I/O pins and the internal logic.

REQUEST TO SEND (RTS)

A LOW level on this input instructs the modem to enter transmit mode. This input must remain LOW for the duration of data transmission. The signal has no effect if DATA TERMINAL READY is HIGH (disabled). A HIGH level on this input turns off the transmitter.

CLEAR TO SEND (CTS)

This output goes LOW at the end of a delay initiated when REQUEST TO SEND goes LOW. Actual data to be transmitted should not be presented to the TRANSMITTED DATA input until a LOW is indicated on the CLEAR TO SEND output. Normally the user should force the TD input HIGH whenever CTS is off (HIGH). This signal never goes LOW as long as DTR is HIGH (disabled). CLEAR TO SEND goes HIGH at the end of a delay initiated when REQUEST TO SEND goes HIGH.

CARRIER DETECT (CD)

A LOW on this output indicates that a valid carrier signal is present at the receiver and has been present for at least a time, t_{CDON} , where t_{CDON} depends upon the selected modem configuration (Table 2). A HIGH on this output signifies that no valid carrier is being received and has not been received for a time, t_{CDOFF} . CARRIER DETECT remains HIGH when DTR is HIGH. Values for t_{CDON} and t_{CDOFF} are configuration dependent and are listed in Table 2.

TRANSMITTED DATA (TD)

Data bits to be transmitted are presented on this input serially; HIGH (mark) corresponds to logic 1 and LOW (space) corresponds to logic 0. This data determines which frequency appears at any instant at the TRANSMITTED CARRIER output pin (Table 2). No signal appears at the TRANSMITTED CARRIER output unless DTR is LOW and RTS is LOW.

RECEIVED DATA (RD)

Data bits demodulated from the RECEIVED CARRIER input are available serially at this output; HIGH (mark) indicates logic 1 and LOW (space) indicates logic 0. Under the following conditions this output is forced to logic 1 because the data may be invalid:

1. When CARRIER DETECT is HIGH
2. During the internal squelch delay at half-duplex line turn around (202/V.23 modes only)
3. During soft carrier turnoff at half-duplex line turn around (202 mode only)
4. When DTR is HIGH
5. When RTS ON and BRTS OFF in V.23/202 modes only
6. During auto-answer sequence

BACK REQUEST TO SEND (BRTS)

Since the 1200 bps modem configurations, Bell 202 and CCITT V.23, permit only half duplex operation over two-wire lines, a low baud rate "backward" channel is provided for transmission from the main channel receiver to the main channel transmitter. This input signal (BRTS) is equivalent to REQUEST TO SEND for the main channel, except it belongs to the backward channel. Note that since the Am7910 contains a single transmitter, RTS and BRTS should not be asserted simultaneously. BRTS is meaningful only when a 202 or V.23 mode is selected by MC₀-MC₄. In all other modes it is ignored.

For V.23 mode the frequency appearing at the transmitted carrier (TC) output pin is determined by a MARK or SPACE at the back transmitted data (BTD) input (Table 2).

For 202 mode a frequency of 387Hz appears at TC when BRTS is LOW and BTD is HIGH. No energy (0.0 volts) appears at TC when BRTS is HIGH. BTD should be fixed HIGH for 202 back channel transmission. The signal, BRTS, then is equivalent to the signal, Secondary Request-to-Send, for 202 S/T modems, or Supervisory Transmitted Data for 202 C/D modems.

BACK CLEAR TO SEND (BCTS)

This line is equivalent to CLEAR TO SEND for the main channel, except it belongs to the back channel. BCTS is meaningful only when a V.23 mode is selected by MC₀-MC₄. This signal is not used in Bell 202 back mode.

BACK CARRIER DETECT (BCD)

This line is equivalent to CARRIER DETECT for the main channel, except it belongs to the backward channel. BCD is meaningful only when a 202 or V.23 mode is selected by MC₀-MC₄. For V.23 back channel mode, BCD turns on when either the MARK or SPACE frequency appears with sufficient level at the received carrier (RC) input.

For 202 back channel mode, BCD turns on in response to a 387Hz tone of sufficient level at the RC input. In this case BCD is equivalent to the signal, Secondary Received Line Signal Detector, for 202 S/T modems, or Supervisory Received Data for 202 C/D modems.

BACK TRANSMITTED DATA (BTD)

This line is equivalent to TRANSMITTED DATA for the main channel, except it belongs to the back channel. BTD is meaningful only when a 202 or V.23 mode is selected by MC₀-MC₄. For 202 back transmission of on/off keying, BTD should be fixed at a HIGH level.

BACK RECEIVED DATA (BRD)

This line is equivalent to RECEIVED DATA (except clamping) for the main channel, except it belongs to the back channel. BRD is meaningful only when a V.23 mode is selected by MC₀-MC₄. Under the following conditions this output is forced HIGH:

1. When BCD is HIGH
2. DTR HIGH
3. V.21/103 mode
4. During auto-answer
5. When BRTS ON and RTS OFF in V.23 modes only

TRANSMITTED CARRIER (TC)

This analog output is the modulated carrier to be conditioned and sent over the phone line.

RECEIVED CARRIER (RC)

This input is the analog signal received from the phone line. The modem extracts the information contained in this modulated carrier and converts it into a serial data stream for presentation at the RECEIVED DATA (BACK RECEIVED DATA) output.

RING

This input signal permits auto-answer capability by responding to a ringing signal from a data access arrangement. If a ringing

signal is detected ($\overline{\text{RING}}$ LOW) and $\overline{\text{DTR}}$ is LOW, the modem begins a sequence to generate an answer tone at the TC output.

XTAL₁, XTAL₂

Master timing of the modem is provided by either a crystal connected to these two inputs or an external clock inserted into XTAL₁. The value of the crystal or the external clock frequency must be 2.4576MHz \pm 0.1%.

V_{CC}

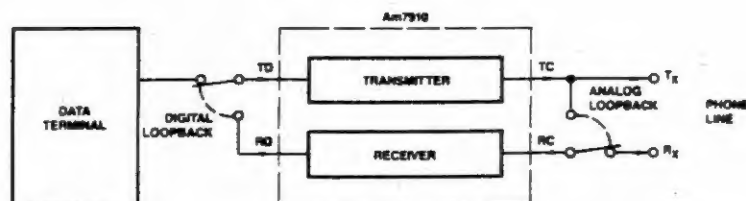
+5 volt power supply. (\pm 5%)

V_{BB}

-5 volt power supply. (\pm 5%)

TABLE 1.

MC ₄	MC ₃	MC ₂	MC ₁	MC ₀	
0	0	0	0	0	Bell 103 Originate 300bps full duplex
0	0	0	0	1	Bell 103 Answer 300bps full duplex
0	0	0	1	0	Bell 202 1200bps half duplex
0	0	0	1	1	Bell 202 with equalizer 1200bps half duplex
0	0	1	0	0	CCITT V.21 Orig 300bps full duplex
0	0	1	0	1	CCITT V.21 Ans 300bps full duplex
0	0	1	1	0	CCITT V.23 Mode 2 1200bps half duplex
0	0	1	1	1	CCITT V.23 Mode 2 with equalizer 1200bps half duplex
0	1	0	0	0	CCITT V.23 Mode 1 600bps half duplex
0	1	0	0	1	Reserved
0	1	0	1	0	
0	1	0	1	1	
0	1	1	0	0	
0	1	1	0	1	
0	1	1	1	0	
0	1	1	1	1	
1	0	0	0	0	Bell 103 Orig loopback
1	0	0	0	1	Bell 103 Ans loopback
1	0	0	1	0	Bell 202 Main loopback
1	0	0	1	1	Bell 202 with equalizer loopback
1	0	1	0	0	CCITT V.21 Orig loopback
1	0	1	0	1	CCITT V.21 Ans loopback
1	0	1	1	0	CCITT V.23 Mode 2 main loopback
1	0	1	1	1	CCITT V.23 Mode 2 with equalizer loopback
1	1	0	0	0	CCITT V.23 Mode 1 main loopback
1	1	0	0	1	CCITT V.23 Back loopback
1	1	0	1	0	Reserved
1	1	0	1	1	
1	1	1	0	0	
1	1	1	0	1	
1	1	1	1	0	
1	1	1	1	1	

Figure 3. Loopback Configurations

012380-3

DGND

Digital signal ground pin.

AGND

Analog signal ground pin (for TRANSMITTED CARRIER and RECEIVED CARRIER).

CAP₁, CAP₂

Connection points of external capacitor/resistor required for proper operation of on-chip analog-to-digital converter.

Recommended values are: $C = 2000\text{pF} \pm 10\%$,
 $R = 100\Omega \pm 10\%$.

RESET

This input signal is for a reset circuit which operates in either of two modes. Refer to Figure 14 and Figure 15 for these two modes. The Am7910 should be reset upon initial application of power.

THEORY OF OPERATION

The Am7910 MODEM consists of three main sections, shown in the block diagram of Figure 2 – Transmitter, Receiver, and Interface Control.

TRANSMITTER (Modulator)

The transmitter, shown in Figure 4, receives binary digital data from a source such as a UART and converts the data to an analog signal using frequency shift keying (FSK) modulation. This analog signal is applied to the phone line through a DAA or acoustic coupler. FSK is a modulation technique which encodes one bit per baud. A logic one applied to the TRANSMITTED DATA (TD) input causes a sine wave at a given frequency to appear at the analog TRANSMITTED CARRIER (TC) output. A logic zero applied to input TD causes a sine wave of a different frequency to appear at the TC output. As the data at the TD input switches between logical one and zero, the TC output switches between the two frequencies. In the Am7910 this switching between frequencies is phase continuous. The frequencies themselves are digitally synthesized sine functions.

The frequencies for each modem configuration available in the Am7910 are listed in Table 3a.

The process of switching between two frequencies as in FSK generates energy at many more frequencies than the two used in the modulation. All the transmitted information can be recovered from a frequency band B Hz wide, where B is the bit rate or maximum rate of change of the digital data at the TD input. This band is centered about a frequency, f_C ,

$$\text{where } f_C = f_1 + (f_2 - f_1)/2$$

(f_1 = lower of two FSK frequencies)

(f_2 = higher of two FSK frequencies)

In addition to this primary information band, there exist side bands containing redundant information. It is desirable to attenuate these bands for two reasons:

1. The phone companies have specifications on the amount of energy allowed in certain frequency bands on the line.
2. If two independent information channels are present simultaneously on the line (e.g. 300 bps full duplex or 1200 bps half duplex with back), the redundant transmitter components may fall in the frequency band of the local receiver channel and interfere with detection. In the Am7910 these redundant and undesirable components are attenuated by digital bandpass filters.

Following the digital bandpass filters, the filtered FSK signal is converted to an analog signal by an on-chip DAC operating at a high sample rate. This analog FSK signal is finally smoothed by a simple on-chip analog low pass filter.

RECEIVER (Demodulator)

A simplified block diagram of the Am7910 FSK receiver is shown in Figure 5. Data transmitted from a remote site modem over the phone line is an FSK-modulated analog carrier. This carrier is applied to the RECEIVED CARRIER (RC) pin via a DAA or acoustic coupler. The first stage of the demodulator is a simple on-chip analog low pass anti-alias filter. The output of this is converted into digital form and filtered by digital bandpass filters to improve the signal to noise ratio and reject other independent channel frequencies associated with the phone line in the case of full duplex configuration. The bandpass filtered output is digitally demodulated to recover the binary data. A carrier detect signal is also digitally extracted from the received line carrier to indicate valid data.

Figure 4. Transmitter Block Diagram

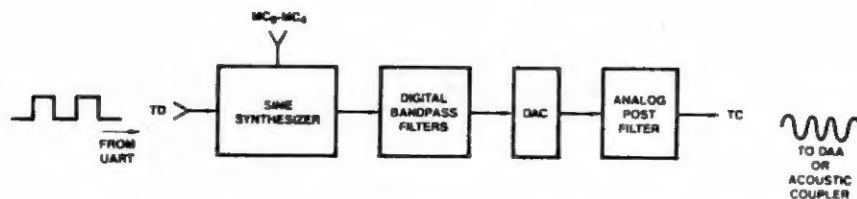
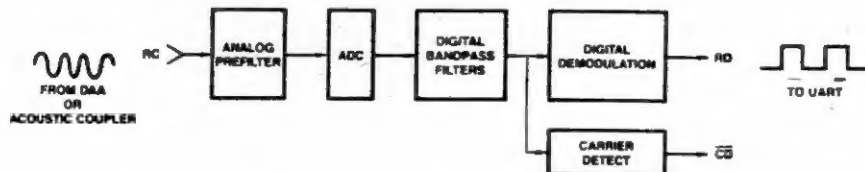


Figure 5. Receiver Block Diagram



INTERFACE CONTROL

This section controls the handshaking between the modem and the local terminal. It consists primarily of delay generation counters, two state machines for controlling transmission and reception, and mode control decode logic for selecting proper transmit frequencies and transmit and receive filters according to the selected modem type. Inputs and outputs from this section are as follows:

REQUEST TO SEND (Main and Back)
 CLEAR TO SEND (Main and Back)
 CARRIER DETECT (Main and Back)
 RING
 MCO-MC4
 DATA TERMINAL READY

Internal logic clamps protocol signals to different levels under certain conditions (e.g., initial conditions).

When Bell 103/113 and V.21 modem configurations are selected, the back channel signals are non-functional.

Figures 8 and 9 depict the sequencing of the two state machines. State machine 1 implements main or back channel transmission and the auto-answer sequence. State machine 2 implements reception on main or back channel.

The state machine powers on to the state labelled INITIAL CONDITIONS. Handshake signals must be the levels listed in Table 2. The machine then waits for DATA TERMINAL READY (DTR) to be turned on. Whenever DTR is turned to the OFF state from an ON condition, each state machine and external signals return to the initial conditions within 25 microseconds. After DTR is turned ON the Am7910 becomes operational as

a modem and the state machines proceed as depicted in the flowcharts.

The definitions of the terms Full Duplex and Half Duplex used in these flowcharts are depicted below (Figs. 6 and 7). "Full Duplex" applies to all 103/113, V.21 modes. "Half Duplex" applies to 202 and V.23, both forward and backward channel.

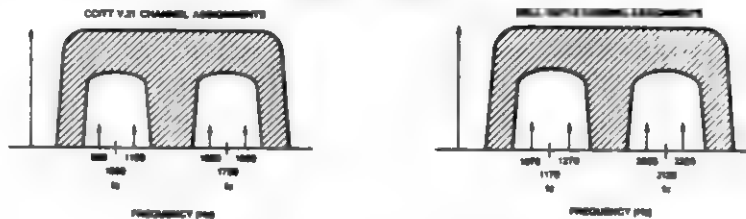
Full Duplex: Data can be transmitted and received simultaneously at a rate of 300 baud. Two independent 300Hz channels are frequency multiplexed into the 3000Hz bandwidth of the phone line. The Am7910 configurations for the Bell 103/113 and CCITT V.21 can be operated full duplex.

Half Duplex: In half duplex with back channel, the modem may transmit at 1200/600 baud and receive at 5/75 baud. Alternatively it may transmit at 5/75 baud and receive at 1200/600 baud. Examples are Bell 202 and CCITT V.23.

TABLE 2
INITIAL CONDITIONS

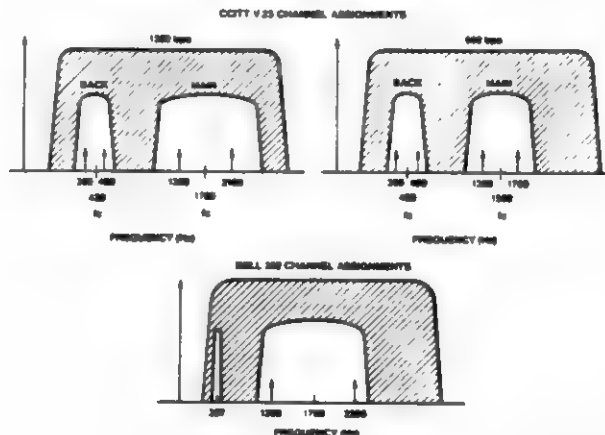
Data Terminal Ready (DTR)	OFF
Request to Send (RTS)	OFF
Clear to Send (CTS)	OFF
Transmitted Data (TD)	Ignored
Back Channel Request to Send (BRTS)	OFF
Back Channel Clear to Send (BCTS)	OFF
Back Channel Transmitted Data (BTD)	Ignored
Ring (RING)	OFF
Carrier Detect (CD)	OFF
Received Data (RD)	MARK
Back Channel Carrier Detect (BCD)	OFF
Back Channel Received Data (BRD)	MARK

Figure 6. Full Duplex



012380-6

Figure 7. Half Duplex



012380-7

TABLE 3(a). FREQUENCY PARAMETERS

Modem	Baud Rate (BPS)	Duplex	Transmit Frequency		Receive Frequency		Answer Tone Freq Hz	Soft Turn Off Tone Hz
			Space Hz	Mark Hz	Space Hz	Mark Hz		
Bell 103 Orig	300	Full	1070	1270	2025	2225	-	-
Bell 103 Ans	300	Full	2025	2225	1070	1270	2225	-
CCITT V 21 Orig	300	Full	1180	980	1850	1650	-	-
CCITT V 21 Ans	300	Full	1850	1650	1180	980	2100	-
CCITT V 23 Mode 1	600	Half	1700	1300	1700	1300	2100	-
CCITT V 23 Mode 2	1200	Half	2100	1300	2100	1300	2100	-
CCITT V 23 Mode 2 Equalized	1200	Half	2100	1300	2100	1300	2100	-
Bell 202	1200	Half	2200	1200	2200	1200	2025	900
Bell 202 Equalized	1200	Half	2200	1200	2200	1200	2025	900
CCITT V 23 Back	75	-	450	390	450	390	-	-
Bell 202 Flare	5	-	*	*	**	**	-	-

* (BRTS LOW) and (STD HIGH): 387Hz at TC

**387Hz at RC: BCD LOW

* (BRTS HIGH) or (STD LOW): 0 volts at TC

**No 387Hz at RC: BCD HIGH

*Meets new CCITT R20 frequency tolerance.

Frequency tolerance is less than ± 0.4 Hz with 2.4576MHz Crystal. Except Bell 202 which is ± 1 Hz (1200 Hz, mark)

TABLE 3(b). TIMING PARAMETERS (Refer to Figures 10, 11 and 12 for Timing Diagrams)

Symbol	Description	Bell 103 Orig	Bell 103 Ans	CCITT V.21 Orig	CCITT V.21 Ans	CCITT V.23 Mode 1	CCITT V.23 Mode 2	CCITT V.23 Mode 2 EQ	Bell 202 EQ	Bell 202 V.23 Back	Bell 202 Back	Units
$t_{RC(ON)}$	Request-to-Send to Clear-to-Send ON Delay	208.3	208.3	400	400	208.3	208.3	208.3	183.3	183.3	-	msec $\pm 0.3\%$
$t_{RC(OFF)}$	Request-to-Send to Clear-to-Send OFF Delay	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	-	msec $\pm 25\%$
$t_{BRC(ON)}$	Back Channel Request-to-Send to Clear-to-Send ON Delay	-	-	-	-	-	-	-	-	-	82.3	msec $\pm 0.64\%$
$t_{BRC(OFF)}$	Back Channel Request-to-Send to Clear-to-Send OFF Delay	-	-	-	-	-	-	-	-	-	0.5	msec $\pm 25\%$
$t_{CD(ON)}$	Carrier Detect ON Delay	94-108	94-108	301-312	301-312	11.4-15.4	11.4-15.4	11.4-15.4	18-22	18-22	-	msec
$t_{CD(OFF)}$	Carrier Detect OFF Delay	21-40	21-40	21-40	21-40	5.4-13.3	5.4-13.3	5.4-13.3	12.4-23.4	12.4-23.4	-	msec
$t_{BCD(ON)}$	Back Channel Carrier Detect ON Delay	-	-	-	-	-	-	-	-	-	17-25	msec
$t_{BCD(OFF)}$	Back Channel Carrier Detect OFF Delay	-	-	-	-	-	-	-	-	-	21-30	msec
t_{AT}	Answer Tone Duration	-	1.9	-	3.0	3.0	3.0	3.0	1.9	1.9	-	sec $\pm 0.44\%$
t_{SI}	Silence Interval before Transmission	1.3	1.3	1.9	1.9	1.9	1.9	1.9	1.3	1.3	-	sec $\pm 0.64\%$
t_{SQ}	Receiver Squelch Duration	-	-	-	-	196.3	196.3	196.3	196.3	196.3	-	msec $\pm 3.3\%$
t_{STO}	Transmitter Soft Turn-Off Duration	-	-	-	-	-	-	-	24	24	-	msec $\pm 2.3\%$
t_{RL}	Minimum RI Low Duration	-	25	-	25	25	25	25	25	25	-	μs

CALL ESTABLISHMENT

Before two modems can exchange data, an electrical connection through the phone system must be established. Although it may assist in call establishment, a modem typically does not play a major role. A call may be originated manually or automatically and it may be answered manually or automatically.

Manual Calling – Manual calling is performed by a person who dials the number, waits for an answer, then places the calling modem into data transmission mode.

Automatic Calling – Automatic calling is typically performed by an automatic calling unit (ACU) which generates the appropriate dialing pulse or dual-tone sequence required to call the remote (called) modem. The ACU also has the ability to detect an answer tone from the called modem and place the calling modem into data transmission mode.

Manual Answering – Manual answering is performed by a person who hears the phone ring, lifts the receiver, causes the called modem to send an answer tone to the calling modem, and places the called modem into data transmission mode.

Automatic Answering – Automatic answering is performed by a called modem with a data access arrangement (DAA). The DAA detects a ringing signal, takes the phone circuit off-hook (corresponding to lifting the receiver) and instructs the called modem to commence the auto-answer sequence. Next the called modem sends out silence on the line, followed by an answer tone. When this tone is detected by the calling modem, the connection is considered to have been established.

The Am7910 provides assistance for automatic answering through the RING signal as follows. Observe the upper right-hand portion of Figure 8(a). Assume that DATA TERMINAL READY (DTR) has recently been asserted to cause exit from the initial conditions. Note that if DTR remains OFF, RING is ignored. Assume also that RTS and BRTS are OFF and that the mode control lines (MCO-MC4) select a normal modem configuration, not a loopback mode. Automatic answering is initiated by receipt of a LOW level at the RING input, causing entrance to the auto-answer sequence depicted in Figure 8(c).

The Am7910 outputs silence (0.0 volts) at its TRANSMITTED CARRIER (TC) output for a time, t_{SIL} , followed by the answer tone for a time, t_{AT} . The CARRIER DETECT (CD) pin is clamped OFF and the RECEIVED DATA (RD) signal is therefore clamped to a MARK (HIGH) during the auto-answer sequence. Upon completion of the answer tone, CD is released. If the mode lines (MCO-MC4) select a 202 or V.23 mode, the transmit filters are set to the forward channel and the receive filters are set to the back channel during the auto answer sequence.

At the end of the auto-answer sequence, return is made to point A in the loop at the upper right-hand portion of Figure 8(a). Note that since the answer flag has been set, the auto-answer sequence cannot be entered again unless DTR is first turned OFF, then ON. At this point the phone line connection has been established and data transmission or reception may begin.

The RING input may be activated from a conditioned DAA Ring Indicator output for automatic answering or it may be activated by a switch for manual answering. Tying RING HIGH will disable the auto-answer function of the Am7910.

DATA TRANSMISSION

Full Duplex

Following call establishment, full duplex data transmission can be started by either the called or calling modem. In other words, if the connection has been established and the modem is looping through point A in Figure 8(a), it no longer matters which is the

called and which is the calling modem. Data transmission is initiated by asserting REQUEST TO SEND (RTS). At this time the TRANSMITTED DATA (TD) input will be released and a modulated carrier can appear at the TRANSMITTED CARRIER (TC) output. Following a delay, t_{RCON} , CLEAR TO SEND (CTS) will turn ON. At this time, data may be transmitted through the TD input. It is a common protocol for the user to always present a MARK at the TD input before RTS is asserted and during the t_{RCON} delay.

Data transmission continues until RTS is turned OFF. Following a short delay, t_{RCOFF} , CTS turns OFF. As soon as RTS goes OFF, the TD input is ignored and the TC output is set to 0.0 volts (silence). After CTS turns OFF, the state machine returns to point A in Figure 8(a).

Half Duplex

When a half duplex mode is selected (202 or V.23), data transmission can be either on the main channel at 1200/600 baud or on the back channel at 5/75 baud. In normal half duplex operation a single modem is either transmitting on the main and receiving on the back channel or vice versa. In the Am7910 control of the transmitter and receiver filters to the proper channel is performed by RTS. When RTS is asserted, the transmitter filters and synthesizer are set to transmit on the main channel; the receiver filters are set to receive on the back channel. Therefore, whenever RTS is on, BRTS should not be asserted since the transmitter cannot be used for the back channel. When RTS is OFF and a half duplex mode is selected, the transmitter filters and synthesizer are set to the back channel; the receiver filters are set to the main channel. If RTS and BRTS are asserted simultaneously, RTS will take precedence. However, if BRTS is asserted before RTS and the back channel data transmission sequence has been entered (Figure 8(b)), RTS will be ignored until BRTS is turned OFF.

The state machine sequences for main and back channel transmission differ slightly and are depicted in Figure 8. Assume the state machine is idling through point A in Figure 8(a).

Main Channel

This transmission sequence is entered if a 202 or V.23 mode is selected and RTS is asserted. Since the receiver is now forced to the back channel, the RECEIVED DATA (RD) signal is clamped to a MARK; and the CARRIER DETECT signal is clamped OFF. The TRANSMITTED DATA input (TD) is released and a carrier appears at the TRANSMITTED CARRIER output which follows the MARK/SPACE applied to TD. RTS turning ON initiates a delay, t_{RCON} , at the end of which the CLEAR TO SEND (CTS) output goes LOW. When CTS goes LOW data may be transmitted through input TD. Data transmission continues until RTS is turned OFF. At this time several events are initiated. First a delay, t_{RCOFF} , is initiated at the end of which CTS turns OFF. The TD input is ignored as soon as RTS goes OFF. If a 202 mode is selected, a soft turn-off tone appears at the TC output for a time, t_{STO} , followed by silence (0.0 volts). For both 202 and V.23 modes a squelch period, t_{SQ} , is initiated when RTS goes OFF. During this period the CD output is clamped OFF, forcing the RD output to a MARK condition. The squelch period begins as soon as RTS goes OFF and thus overlaps both t_{RCOFF} and t_{STO} . At the end of the squelch period, the state machine returns to the idle loop at point A in Figure 8(a).

The reasons for squelch and soft-turnoff are as follows:

Soft Turn-Off: When RTS is turned OFF at the end of a message, transients occur which may cause spurious space signals to be received at a remote modem. During soft turn-off the modem transmits a soft carrier frequency for a period, t_{STO} , after RTS is

turned OFF. This results in a steady MARK on the RECEIVED DATA (RD) line of the remote modem.

Squelch: The local receiver must be turned OFF after $\overline{\text{RTS}}$ is OFF, until the start of carrier detect, so that line transients are not demodulated. The process of disabling the receiver after $\overline{\text{RTS}}$ is turned OFF is called squelching.

Back Channel

This transmission sequence, shown in Figure 8(b), is entered if a 202 or V.23 mode is selected, $\overline{\text{RTS}}$ is OFF, and $\overline{\text{BRTS}}$ is asserted. The BACK CARRIER DETECT (BCD) output is forced OFF and the BACK RECEIVED DATA (BRD) output is clamped to a MARK. The BACK TRANSMITTED DATA input (BTD) is released and a carrier appears at the TC output which follows the MARK/SPACE applied to BTD. Turning on $\overline{\text{BRTS}}$ initiates a delay, t_{BRCON} , at the end of which the BACK CLEAR TO SEND (BCTS) output goes LOW. When BCTS goes LOW data may be transmitted through input BTD. Data transmission continues until $\overline{\text{BRTS}}$ is turned OFF. The input BTD is immediately ignored and the TC output is silenced (set to 0.0 volts). Following a short delay, t_{BRCOFF} , the output BCTS goes OFF. The signals BCD and BRD are released and the state machine returns to idle at point A of Figure 8(a).

In 202 back channel mode, BTD should be tied HIGH. Then $\overline{\text{BRTS}}$ controls the ON/OFF keying modulation. When $\overline{\text{BRTS}}$ is LOW, 387Hz appears at the TC output; when $\overline{\text{BRTS}}$ is HIGH, 0 volts appears at TC.

DATA RECEPTION

Data reception is controlled by state machine 2 and depicted in Figure 9. At power on the machine enters initial conditions and remains there until $\overline{\text{DTR}}$ is asserted. It then loops until either CARRIER DETECT ($\overline{\text{CD}}$) or BACK CARRIER DETECT (BCD) occurs.

Full Duplex

In full duplex data reception, CARRIER DETECT may appear at any time after the phone connection has been established. Reception is independent of transmission. When the receiver detects a valid carrier for at least a time, t_{CDON} , the output $\overline{\text{CD}}$ is turned ON, the RECEIVED DATA (RD) output is released, and valid data can be obtained at RD. Data is received until the receiver detects loss of carrier for at least a time, t_{CDOFF} . At this time the $\overline{\text{CD}}$ output is turned OFF and RD is clamped to a MARK. The state machine returns to the idle loop at point E.

Half Duplex

As discussed in the data transmission section above, when a half duplex mode has been selected, the signal $\overline{\text{RTS}}$ controls whether the main channel is transmitting or receiving. The back channel can only do the opposite from the main. If $\overline{\text{RTS}}$ is OFF, then CARRIER DETECT may be asserted and the data reception sequence is identical to that discussed above for full duplex reception. As long as $\overline{\text{RTS}}$ remains OFF, BACK CARRIER DETECT will never be asserted. If $\overline{\text{RTS}}$ is ON, then CARRIER DETECT will never be asserted. Instead the receiver will look for a valid carrier in the back channel frequency band. If a valid carrier exists for at least a time, t_{BCDON} , the output BACK CARRIER DETECT (BCD) is turned ON, the BACK RECEIVED DATA (BRD) output is released and valid data can be obtained at BRD. Data is received until the receiver detects loss of back channel received signal for at least time, t_{BCDOFF} . At this time the BCD output is turned OFF. Data output, BRD, is clamped to a MARK if a V.23 mode is selected. For 202 back channel mode, BCD represents the received data. The BRD output can be ignored. The state machine returns to the idle loop at point E.

LOOPBACK

Ten modes exist to allow both analog and digital loopback for each modem specification met by the Am7910. When a loopback mode is selected, the signal processing (filters, etc.) for both the transmitter and receiver is set to process the same channel or frequency band. This allows the analog output, TRANSMITTED CARRIER, and the analog input, RECEIVED CARRIER, to be connected for local analog loopback. Alternatively the digital data signals, TD and RD or BTD and BRD, can be connected externally, allowing a remote modem to test the local modem with its digital data signals looped back.

When a loopback mode is selected, the state machine sequences are altered slightly. First, auto-answer is disabled. Second, if a half duplex loopback mode is selected (202 or V.23), the local CARRIER DETECT/BCD is not forced OFF when $\overline{\text{RTS}}/\overline{\text{BRTS}}$ is asserted.

The 202 and V.23 main loopback modes allow use in a 4-wire configuration at 1200 bps.

Figure 8(a). Transmit Main Channel State Diagram

Figure 9. Receiver Main/Back Channel State Diagram

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graph TD
    Start([INITIAL CONDITIONS]) --> DTR{DTR ON}
    DTR -- NO --> E((E))
    DTR -- YES --> AnalogLoopBack{ANALOG LOOP BACK}
    AnalogLoopBack -- YES --> AnalogLoopBack
    AnalogLoopBack -- NO --> CarrierDetectedMain{CARRIER DETECTED}
    CarrierDetectedMain -- YES --> AnalogLoopMain{ANALOG LOOP MAIN}
    CarrierDetectedMain -- NO --> FullDuplex{FULL DUPLEX}
    FullDuplex -- YES --> BackChannelCarrierDetectedMain{BACK CHANNEL CARRIER DETECTED}
    FullDuplex -- NO --> BackChannelCarrierDetectedMain
    BackChannelCarrierDetectedMain -- YES --> IsCDONCompleteMain{IS CDON COMPLETE}
    BackChannelCarrierDetectedMain -- NO --> BackChannelCarrierDetectedMain
    IsCDONCompleteMain -- YES --> BCDataReceptionMain[BC DATA RECEPTION]
    IsCDONCompleteMain -- NO --> BackChannelCarrierDetectedMain
    BCDataReceptionMain --> BackChannelCarrierDetectedBC{BACK CHANNEL CARRIER DETECTED}
    BackChannelCarrierDetectedBC -- YES --> BCDataReceptionMain
    BackChannelCarrierDetectedBC -- NO --> IsBCDOFFCompleteMain{IS BCDOFF COMPLETE}
    IsBCDOFFCompleteMain -- YES --> Bell202{BELL 202}
    IsBCDOFFCompleteMain -- NO --> BackChannelCarrierDetectedBC
    Bell202 -- YES --> BCDOffMain[BCD OFF]
    Bell202 -- NO --> BCDOffMarkMain[BCD OFF BRD = MARK]
    BCDOffMain --> ReturnToEMain((RETURN TO E))
    BCDOffMarkMain --> ReturnToEMain

    Start --> IsCDONCompleteMain
    IsCDONCompleteMain -- NO --> IsCDONCompleteMain
    IsCDONCompleteMain -- YES --> CDONReleasedMain[CD ON RD RELEASED SET ANSWERED]
    CDONReleasedMain --> DataReceptionMain[DATA RECEPTION]
    DataReceptionMain --> CarrierDetectedMain
    CarrierDetectedMain -- YES --> DataReceptionMain
    CarrierDetectedMain -- NO --> IsCDOFFCompleteMain{IS CDOFF COMPLETE}
    IsCDOFFCompleteMain -- YES --> CDOFFMarkMain[CD OFF RD = MARK]
    IsCDOFFCompleteMain -- NO --> CarrierDetectedMain
    CDOFFMarkMain --> ReturnToEMain
  
```

The diagram illustrates the state transitions for the Receiver Main/Back Channel. It begins with 'INITIAL CONDITIONS' leading to a decision 'DTR ON'. If 'DTR ON' is 'NO', the process returns to 'E'. If 'YES', it proceeds to 'ANALOG LOOP BACK'. If 'ANALOG LOOP BACK' is 'YES', it loops back. If 'NO', it checks 'CARRIER DETECTED'. If 'CARRIER DETECTED' is 'YES', it checks 'ANALOG LOOP MAIN'. If 'ANALOG LOOP MAIN' is 'YES', it checks 'FULL DUPLEX'. If 'FULL DUPLEX' is 'YES', it checks 'BACK CHANNEL CARRIER DETECTED'. If 'BACK CHANNEL CARRIER DETECTED' is 'YES', it checks 'IS CDON COMPLETE'. If 'IS CDON COMPLETE' is 'YES', it proceeds to 'BC DATA RECEPTION'. If 'IS CDON COMPLETE' is 'NO', it loops back to 'BACK CHANNEL CARRIER DETECTED'. 'BC DATA RECEPTION' leads to another 'BACK CHANNEL CARRIER DETECTED' check. If 'YES', it loops back to 'BC DATA RECEPTION'. If 'NO', it checks 'IS BCDOFF COMPLETE'. If 'IS BCDOFF COMPLETE' is 'YES', it checks 'BELL 202'. If 'BELL 202' is 'YES', it proceeds to 'BCD OFF', which then returns to 'E'. If 'BELL 202' is 'NO', it proceeds to 'BCD OFF BRD = MARK', which then returns to 'E'. If 'IS BCDOFF COMPLETE' is 'NO', it loops back to 'BACK CHANNEL CARRIER DETECTED'. The main channel logic starts with 'INITIAL CONDITIONS' leading to 'IS CDON COMPLETE'. If 'IS CDON COMPLETE' is 'NO', it loops back. If 'YES', it proceeds to 'CD ON RD RELEASED SET ANSWERED', then 'DATA RECEPTION', then 'CARRIER DETECTED'. If 'CARRIER DETECTED' is 'YES', it loops back to 'DATA RECEPTION'. If 'NO', it checks 'IS CDOFF COMPLETE'. If 'IS CDOFF COMPLETE' is 'YES', it proceeds to 'CD OFF RD = MARK', which then returns to 'E'. If 'IS CDOFF COMPLETE' is 'NO', it loops back to 'CARRIER DETECTED'.